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SEED PHYSIOLOGY, PRODUCTION & TECHNOLOGY

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Yield, Quality, and Nitrogen Use of Inbred Corn with Varying Numbers of Leaves Removed during Detasseling

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ABSTRACT

Detasseling is used in hybrid corn (*Zea mays* L.) seed production to ensure harvested seeds have the desired genetic complement. Both mechanical and hand detasseling result in loss of some leaf tissue and plant N. The objective of this study was to determine if seed yield and quality and N content of grain and stover were affected by leaf removal during detasseling. The treatments evaluated were removal of tassel only, tassel plus one leaf, tassel plus two leaves, tassel plus three leaves, tassel plus four leaves, and no tissue removed (control). The leaf area index (LAI) declined linearly, about 0.16 LAI units per leaf removed. Grain and stover yield also declined linearly with number of leaves removed with the tassel (r^2 = 0.97 and 0.92, respectively). Each leaf removed reduced grain yield about 0.36 Mg ha^{-1}. Yield reduction was caused by decreased kernel size. Grain and stover N concentration and amount of N in stover did not vary among detasseled treatments. However, total N in the grain declined linearly as number of leaves removed increased (r^2 = 0.97). Warm and cold germination and warm germination after accelerated aging were not affected by leaf removal during detasseling. Results reported here suggest that when leaves are removed from the plant at detasseling, the loss of photosynthetic capacity, the ability to intercept light, and plant N all contribute to grain yield reduction.

THE PRODUCTION OF HYBRID CORN seed requires that only pollen from the male parent be available for pollination in the seed production field. Detasseling (both mechanical and hand) is used to prevent pollen shed from the female parent. The number of leaves removed with the tassel depends on plant morphology, the time of detasseling relative to time of tassel emergence, pollen shed and silk emergence, and settings on mechanical detasseling machines. As many as four leaves may be removed from the female parent to ensure complete tassel removal and genetic purity of seed produced. These leaves represent a significant source of photosynthate and N for the developing kernels. Their loss may impact yield and quality of the hybrid seed produced and the N used by the crop.

Several studies have been conducted to evaluate the influence of tassel removal on grain yield. Dungan and Woodworth (1939), Kiesselbach (1945), and Hunter et al. (1969; 1973) reported reductions in grain yield and kernel mass when leaves were removed with tassels. Removal of the tassel may increase yield because of improved light interception by underlying photosynthetically active tissue (Duncan et al., 1967; Hunter et al., 1969) and more favorable translocation of photosynthate to the grain (Mostert and Marais, 1982), but results are variable depending on interplant competition, water availability, and soil fertility (Grogan, 1956; Hunter et al., 1973).

Inbred lines produce far less grain than hybrids. Under irrigation in the central Platte River Valley of Nebraska, a prime U.S. hybrid seed production area, yields vary greatly among inbreds, but average about 3.5 Mg ha^{-1}. Although production is low, the value per unit of yield is 6 to 10 times greater than that of feed grain. Because of the high seed value, producers are encouraged by contracting companies and economic logic to maximize yields. Producers try to keep soil water (in irrigated areas) and fertilizer N non-limiting. A survey by Schepers et al. (1991a,b) indicated the average seed producer in the Central Platte Natural Resource District applied 130 kg N ha^{-1}. This rate of N application was twice the calculated amount of N removal by the crop (assuming 18 kg N removed kg^{-1} corn removed) and fertilizer recommendations for feed grain production based on soil tests. Environmental awareness by producers, seed companies, and the general public has increased the need for data to use in recommending fertilizer N application rates for hybrid seed production. The objective of this study was to determine the effect of leaf removal during detasseling on seed yield, kernel quality, and N use.

MATERIALS AND METHODS

This experiment was conducted during 1991 and 1992 in the central Platte River valley near Shelton, NE, (40° N, 99° W) on a Hord silt loam (fine-silty, mixed, mesic Cumulic Haplustolls) at the site of the Nebraska Management Systems Evaluation Area (MSEA) project. Before planting, stover from the previous crop (corn feed grain) was chopped and the soil tilled twice with a tandem disk. The inbred line, N192, was planted at 8.2 kernel m^{-2} on 7 May 1991 and 6.5 kernel m^{-2} on 30 April 1992 in 0.91-m rows. Plant stands were thinned to 8.0 plants m^{-2} in 1991 and 6.0 plants m^{-2} in 1992, prior to the four-leaf stage. Weeds were controlled with a combination of herbicides, mechanical cultivation, and hand hoeing. Anhydrous ammonia was applied at 80 kg N ha^{-1} at the five-leaf stage. The experimental area was irrigated as needed using management practices typical for the area with a linear drive

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Abbreviations: C, control—no tissues removed; LAI, leaf area index; T only, tassel only removed; T+1, tassel plus one leaf removed; T+2, tassel plus two leaves removed; T+3, tassel plus three leaves removed; T+4, tassel plus four leaves removed.

sprinkler. A total of 33.5 cm of irrigation water was applied in 1991 and 20.8 cm in 1992.

The treatments were removal of (i) tassel only, (ii) tassel plus one leaf, (iii) tassel plus two leaves, (iv) tassel plus three leaves, (v) tassel plus four leaves, and (vi) control. The treatments were assigned to each of six blocks in a randomized complete block design. Each experimental unit was eight-rows wide and 5.33 m long in 1991 and 6.1 m long in 1992. The tassels and leaves were removed from the center six rows of the eight-row plots on 7 July 1991 and 27 July 1992. Data collection was restricted to the center two rows of each plot.

The tassels and leaves removed during treatment application were collected, weighed, and ground. Subsamples were collected, weighed, dried, reweighed, and analyzed for N concentration. Nitrogen concentration of all samples was determined by the Dumas combustion technique (Schepers et al., 1989). Leaf area index was measured 21 d after tassel and leaf removal with an LAI-2000 Plant Canopy Analyzer (LI-COR, Inc., Lincoln, NE)[1].

About 1 wk after physiological maturity (black layer visible), all ears from the center two rows of each plot were harvested. Ears were dried at 40°C and kernels removed with a motor driven single ear sheller. Grains were weighed and yield reported at 0.155 kg water kg^{-1} tissue. Kernel mass was determined and number of kernels plant^{-1} calculated. Salable seed was defined as the fraction of a random 0.5-kg sample of kernels less than 10.32-mm and greater than 6.35-mm diam., as determined by sieving for 2 min. Warm and cold (1992 only) germination and warm germination after accelerated aging were also determined (Association of Official Seed Analysts, 1983) on grain samples treated with captan {*N*-[(trichloromethyl)thio]-4-cyclohexene-1, 2-dicarboximide}. Grain N concentration was determined by the Dumas combustion technique (Schepers et al., 1989).

After grain harvest, stover from 3.1-m lengths of the center two rows of each experimental unit was cut at the soil surface, weighed, and ground. Subsamples were collected for water content and N concentration determination. The mass of shelled cobs was included in the stover weights reported.

All data were analyzed by analysis of variance and treatment effects evaluated by specific contrasts. For measurements where the linear, quadratic, or cubic components of variance were significant, regression coefficients for the appropriate equation were estimated by the least-squares method and regressed with numbers of leaves removed. All differences reported are significant at $P \leq 0.01$.

RESULTS AND DISCUSSION

The inbred used in this study, N192, was selected from a cross between CM105 × B73. CM105 is an early maturing selection from B14. Both parents of N192 are from the Iowa Stiff Stalk Synthetic. This general pool of inbred lines is widely used as a female parent in commercial corn hybrids and represents one of the two main heterotic groups. Although results from N192 may not reflect specific responses to detasseling and leaf removal of all inbreds in use today, its parentage is similar to that of many widely used inbreds and it is representative of the larger group of inbreds belonging to the Stiff Stalk heterotic group, to which conclusions drawn from this study may be applied.

Yield and yield components (Table 1), N concentration and content (Table 2), and seed germination (Table 3) were strongly influenced by the year source of variation. However, no year x treatment interaction effects were significant. Therefore, data from the 1991 and 1992 seasons were combined and reported as mean effects.

Leaf area index declined linearly as number of leaves removed during detasseling increased (Table 1). With each leaf removed, LAI was reduced by 0.16 units (r^2 = 0.78). Removal of four leaves with the tassel reduced

[1] Mention of trademark or registered product name does not imply a guarantee by the Agricultural Research Service or the University of Nebraska or suggest that the product is superior to others that may have similar function.

Table 1. Effect of leaf removal during detasseling on yield and yield components in the corn inbred line N192.

Treatment		Leaves above ear	LAI†	Yield		Kernel mass	Kernel no.	Salable seed‡		
				Grain	Stover			Fraction	Yield	Units§
		leaves	–	Mg ha^{-1}		mg kernel^{-1}	no. plant^{-1}	–	Mg ha^{-1}	unit ha^{-1}
Control		5.4	2.14	4.93	5.29	226	310	0.894	4.42	243
T only		5.2	2.14	4.81	5.40	233	302	0.908	4.38	233
T + 1		4.4	2.09	4.80	5.09	229	299	0.897	4.33	234
T + 2		3.3	2.05	4.47	5.03	225	298	0.890	4.01	221
T + 3		2.5	1.98	4.23	4.35	214	297	0.869	3.70	214
T + 4		1.4	1.58	3.68	3.75	201	284	0.844	3.13	192
SE		0.5	0.08	0.10	0.17	2	6	0.006	0.09	5
ANOVA Table										
Source	df	Mean Squares								
Years	1	4.18**	5.47**	32.44**	72.68**	37 032**	57 272**	0.075**	39.12**	25 626**
Blocks(years)	10	0.02	0.06	0.12	0.41	384	443	0.003	0.24	250
Treatment	5	29.56**	0.55**	2.67**	4.87**	1647**	856	0.007**	3.07**	3960**
Control vs T only	1	0.24**	<0.01	0.09	0.07	269	374	0.001	0.01	604
T only vs others	1	23.34**	0.46	2.50**	6.82**	2321**	525	0.010**	3.30**	2958**
Within others										
linear	1	50.37**	1.57**	7.79**	13.15**	5390**	1321	0.020**	9.20**	10 539**
quadratic	1	<0.01	0.38	0.14	0.88	176	452	0.001	0.19	236
cubic	1	0.12	0.05	0.09	0.29	17	73	<0.001	0.05	266
Year × treatment	5	0.05	0.10	0.12	1.08	52	1192	0.001	0.10	154
Error	50	0.03	0.07	0.13	0.35	56	474	0.0004	0.10	318

** Indicates the effect is significant at $P \leq 0.01$ according to the *F*-test.
† Measured 21 d after detasseling.
‡ Diameter between 6.35 and 10.32 mm.
§ Unit = 80 000 seeds.

Table 2. Effect of leaf removal during detasseling on nitrogen content and uptake in the corn inbred line N192.

Treatment		Removed tissue		Grain		Stover		
		N conc.	N content	N conc.	N content	N conc.	N content	Total N content†
		g N kg^{-1}	kg N ha^{-1}	g N kg^{-1}	kg N ha^{-1}	g N kg^{-1}	kg N ha^{-1}	kg N ha^{-1}
Control		–	–	18.6	90.2	10.1	53.7	143.8
T only		26.9	4.3	18.0	88.0	10.4	53.2	145.5
T + 1		26.0	6.1	18.4	87.7	10.5	51.2	145.0
T + 2		24.6	9.5	18.0	81.9	10.5	46.2	137.7
T + 3		25.7	17.0	18.1	76.1	11.1	52.0	145.1
T + 4		24.8	23.2	17.8	65.4	10.4	47.1	135.8
SE		0.4	0.6	0.2	1.7	0.2	3.0	3.2
ANOVA Table								
Source	df	Mean Squares						
Years	1	0.4	49.9**	0.4	8504.9**	0.3	6722.4**	28 144**
Blocks(years)	10	0.6	3.2	<0.1	75.4	0.2	149.7	311
Treatment	5	1.0**	755.5**	0.1	1063.6**	0.1	119.2	218
Control vs T only	1	–	20.4	0.2	27.7	0.1	1.3	16
T only vs others	1	2.4**	902.1**	<0.1	1006.6**	0.1	158.4	204
Within others								
linear	1	0.4	2078.3**	0.2	3158.0**	<0.1	23.5	239
quadratic	1	<0.1	24.4	<0.1	71.0	0.1	<0.1	12
cubic	1	0.1	17.1	<0.1	13.1	0.2	276.6	595
Year × treatment	5	0.2	3.1	0.1	31.6	0.2	158.3	129
Error	50	0.2	4.8	0.1	34.8	0.1	111.8	121

** Indicates the effect is significant at $P \leq 0.01$ according to the F-test.
† Sum of N content in removed tissue, grain, and stover.

LAI by 25%. Although ANOVA (Table 1) indicated the linear response for LAI was significant at $P \leq 0.01$, the probability of a greater mean square for the quadratic component was $P = 0.026$. Removing Leaves 3 or 4 had a greater impact on LAI than removal of Leaves 1 and 2 because of the difference in size of leaves; leaves nearest the ear were larger than those further from the ear (Dwyer and Stewart, 1986; Keating and Wafula, 1992). The average number of leaves remaining above the ear after treatment application ranged from 5.4 for the control to 1.4 for T+4 (Table 1) and declined linearly with the number of leaves removed ($r^2 = 0.99$). Reduced

Table 3. Effect of leaf removal during detasseling on cold and warm germination and germination after accelerated aging in the corn inbred line N192.

Treatment		Germination		Accelerated aging
		Cold†	Warm	
		%		
Control		93.5	93.4	95.3
T only		94.7	95.8	94.9
T + 1		93.7	95.1	96.1
T + 2		92.0	95.4	95.6
T + 3		92.5	94.4	93.1
T + 4		93.8	95.1	95.2
SE		1.6	0.7	0.9
ANOVA Table				
Source	df	Mean Squares		
Years	1	–	331.5**	82.3**
Blocks(years)	10	15.9	14.4	22.3
Treatment	5	5.6	9.0	12.9
Control vs T only	1	4.1	36.3	1.0
T only vs others	1	13.3	6.7	0.1
Within others				
linear	1	0.3	0.6	15.0
quadratic	1	13.5	0.3	21.3
cubic	1	0.5	5.4	26.7
Year × treatment	5	–	7.7	24.1
Error	50	15.1	6.8	9.6

** Indicates the effect is significant at $P \leq 0.01$ according to the F-test.
† Cold germination not measured in 1991.

leaf area resulted in reduced grain and stover yields (Table 1). Grain yields declined 0.36 Mg ha^{-1} for each leaf removed with the tassel. Stover yields also declined with number of leaves removed by 0.32 Mg ha^{-1} per leaf. Although the exact difference in yield (either grain or stover) resulting from removal of each leaf varied, the overall effect of leaf removal was linear ($r^2 = 0.97$ for grain yield and 0.92 for stover yield). Similar to the reduction in LAI, stover and grain yields were reduced by about 25% with the removal of four leaves.

Kernel mass declined by 9.5 mg kernel^{-1} ($r^2 = 0.96$) for each leaf removed with the tassel (Table 1). Removal of four leaves reduced kernel mass by about 10% compared to the control. The fraction of kernels of salable size decreased as the number of leaves removed at detasseling increased. Production of salable seed declined about 2% for each leaf removed with the tassel. The number of kernels per plant was not affected by the defoliation treatments. This result is not consistent with reports by Tollenaar and Daynard (1978), Egharevba et al. (1976), and Vasilas and Seif (1985). In these earlier reports, the least severe treatment tested resulted in about a 50% reduction in LAI or total leaf tissue. In some cases (Vasilas and Seif, 1985) severe defoliation did not cause reductions in kernel number for all inbreds. Our most severe treatment, T+4, represented a 26% reduction in LAI and retained 1.4 leaves above the ear. Differences in severity of treatments may account for the apparent conflict in results.

The combination of reduced grain yield and reduced fraction of salable seed resulted in production ranging from 4.42 Mg ha^{-1} for the control to 3.13 for T+4 (Table 1). By dividing by kernel mass, the number of units (80 000 kernels) of seed corn produced per unit of land was calculated. Units of salable seed declined linearly with number of leaves removed with the tassel ($r^2 = 0.95$; Table 1).

Nitrogen concentration of removed tissue varied slightly, with the T only treatment having greater N concentration than treatments in which leaves were removed with the tassel (Table 2). All treatments which had leaves removed also had a greater amount of stalk removed. The greater amount of stalk tissue in the sample probably caused the reduction in N concentration. Total N removed from the canopy during detasseling increased linearly with number of leaves removed. Nitrogen concentration of the grain and stover did not vary among treatments (Table 2). The total N content of the grain was related to grain yield ($r = 0.91$) and not grain N content ($r = 0.08$), and declined by about 7.3 kg N ha^{-1} for each leaf removed (25% less N removed in grain when four leaves were removed at detasseling compared to no leaf removal at detasseling). Interestingly, when total plant N content (sum of N content in removed tissue, grain, and stover) was compared, no treatment differences were observed (Table 2). This result suggests that the majority of N in the plant at harvest was present prior to detasseling.

Both grain and stover yields declined as more leaves were removed at detasseling. The decline in N content of grain and stover was associated with a decline in dry matter production, not a change in grain or stover N concentration. Loss of photosynthetic tissue, the ability to intercept light, and plant N contributed to the change in crop productive capacity.

Seed quality, measured by warm and cold germination and accelerated aging, was not influenced by leaf removal treatments (Table 3). The somewhat low germination values reported may have resulted because the samples were screened and sorted only to remove broken kernels.

To completely evaluate the interaction of leaf removal at detasseling and N fertilizer recommendations, more extensive experiments must be initiated. However, the results presented here suggest that nearly all N in the plant at harvest was taken up prior to detasseling and that the nitrate leaching potential of seed production fields is independent of the amount of leaf material removed with the tassel.

From a practical standpoint, the producer may have little choice in how many leaves are removed with the tassel. All tassels on the female parent must be removed to ensure the genetic purity of the hybrid seed produced. With a crop having such a high value, the error of removing one more leaf than necessary (and reducing yields) to eliminate all female tassels is less costly than the error of removing too few leaves and producing a seed crop containing an unacceptable amount of seed originating from self-pollinated female plants.

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